



DOE Solid-State Lighting Program



Modest Investments, Extraordinary Impacts

Suddenly, solid-state lighting seems to be everywhere. Yet SSL technology is actually in its infancy. When it comes to U.S. energy and carbon savings, more than 95 percent of its potential remains untapped.

Shaping the Future of Solid-State Lighting

Today, LED (light emitting diode) technologies illuminate grocery display cases, make parking garages and streets brighter and safer, and proliferate on retail shelves. Homeowners and businesses are making the switch to SSL at an ever-faster pace, as product costs fall and performance keeps improving. The result: Americans are already saving hundreds of millions of dollars on energy, while reducing carbon emissions and making our nation less dependent on fossil-generated power.

Despite these successes, the vast majority of SSL's upside is yet to come.

Fully capitalizing on the promise of LED and OLED (organic LED) technologies will catapult our nation forward in creating a clean energy future. Energy-efficient technologies like SSL not only will slow consumption of fossil fuels, they will go hand-in-hand with making renewable energy more competitive. For example, by substantially reducing electricity use for lighting, SSL will make it far more affordable and practical to construct zero-energy buildings—buildings so energy-efficient that renewable energy systems can offset all or most of their annual energy consumption.

Still, the future of SSL is anything but certain. Will technological improvement continue at a rapid pace, enabling our nation to realize the full potential energy and carbon savings of SSL? And will we reap the maximum possible business and job growth, by attracting investors to locate engineering and manufacturing operations in the United States?



DOE-sponsored **industry workshops** bring together researchers, manufacturers, lighting users, energy efficiency programs, and other stakeholders to share up-to-the-minute data on SSL technology performance. Stakeholder input helps shape DOE R&D and technology development strategies.

Many hurdles stand in the way, requiring breakthroughs in materials and processes, control systems, product design, and manufacturing. These are the challenges being tackled by the U.S. Department of Energy (DOE), in partnership with industry, through its Solid-State Lighting Program.

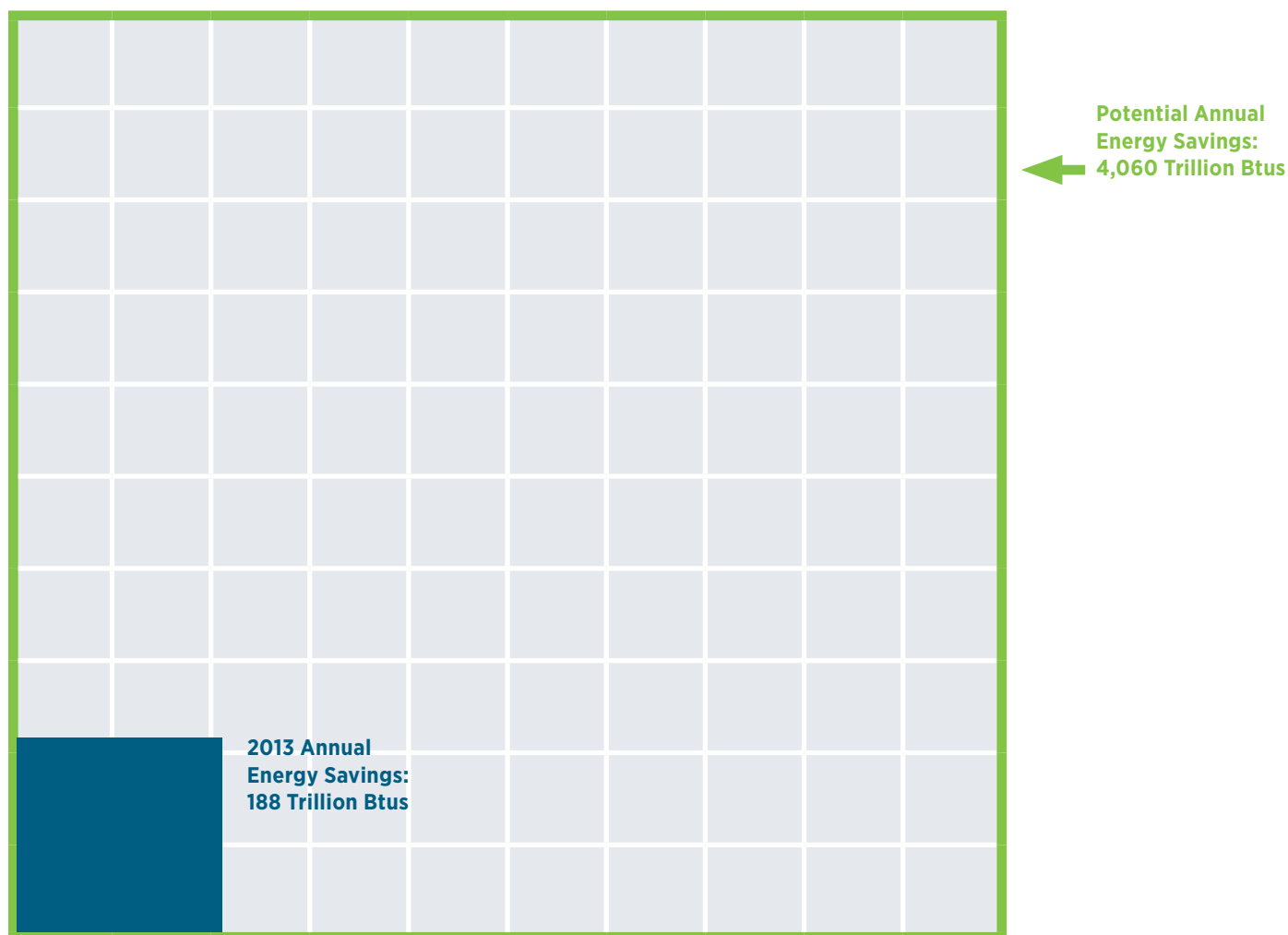
DOE strategies build on a strong record of progress.

In the past decade, modest yet highly strategic investments by DOE have helped make the United States the epicenter of SSL innovation. DOE has spurred the

▼ **It is still early days for SSL.** When it comes to U.S. energy and carbon savings, more than 95 percent of its potential remains untapped. In the best-case scenario, annual savings could grow from 188 trillion Btus in 2013 to an ultimate level of more than 4,000 trillion Btus.

industry to achieve rapid improvements in efficacy, cost, and value-added features in SSL products by investing in competitively selected cost-shared R&D projects that reduce the risks of early-stage technology development; and by providing manufacturers with objective insights into product performance in order to fuel ongoing market-based technology development. Along the way, DOE has continually evolved its program strategies and investments, to keep pace with technological progress and to deliver the best possible benefits for U.S. taxpayers.

DOE has set a high bar for SSL in the next decade, challenging the industry with aggressive “reach” goals for efficacy and performance, and cultivating the climate of innovation essential to new SSL-related business and job creation in the United States.



Btu: British thermal unit

Sparking a Lighting Revolution

Back in 2003, solid-state lighting was generating virtually no illumination. Yet it **was** generating plenty of excitement. Scientists had documented the prospects for LEDs and OLEDs to produce high-quality white light at far greater levels of energy efficiency than traditional incandescent or fluorescent technologies.

At the direction of Congress, DOE charted a pathway for rapidly moving SSL from the laboratory to the marketplace, in partnership with leaders in industry and academia. The driving purpose of DOE's involvement was to move the industry farther and faster, toward higher levels of efficiency and quality than would otherwise be achieved.

Wise federal investments: making a real difference.

Through the Solid-State Lighting Program, DOE has worked in close collaboration with innovators in the field, to topple technical and design barriers and to lay the foundation for early market successes.

Many barriers have been successfully tackled:

- The first market-available white LED products tested by DOE in 2006 were no more efficient than the incandescent bulb, yielding less than 20 lumens per watt (lm/W). Today, DOE's LED Lighting Facts® database lists medium screw-based replacement lamps with efficacies of up to 116 lm/W. The most efficient LED luminaires reach efficacies of 150 lm/W.
- Initially, only narrow niche applications of LEDs offered cost and performance benefits. Today, LED products are beginning to become competitive in a wider range of applications. Specially designed LED luminaires—capable of delivering far greater efficacy than replacement bulbs—are starting to gain market share.
- Early buyers lacked the trusted metrics and uniform standards to make sound decisions about where and how to use SSL. Today, the whole lighting industry has climbed the learning curve. Spurred by DOE's technical support and partnership with standards organizations, the industry now has essential tools such as standard test procedures and product qualification programs.



The **Next Generation Luminaires™ competition**, co-sponsored by DOE, recognizes excellence in commercial SSL products. Manufacturers compete vigorously to participate in NGL, hoping to benefit from in-depth feedback provided by the leading lighting experts who serve as judges.

- DOE recognized early on that, without focused action, American leadership in SSL technology would not necessarily translate into domestic manufacturing operations and jobs. Today, thanks to strategic investments by DOE and partners in efficient, flexible manufacturing technologies, the United States can be highly competitive as a location for SSL engineering and production. One sign is the recent “onshoring” by several companies of operations previously conducted overseas.

What’s the bottom line?

Program accomplishments to date have been impressive. Just consider that the 200-plus cost-shared R&D projects funded to date have resulted in more than 180 patents and a huge industry footprint, with literally millions of SSL products currently on the market that are based on at least some DOE-funded R&D. Those products yielded about \$2.8 billion in U.S.

▼ New SSL products are being introduced at a blazing pace.

Yet, to date, energy-saving impacts have been minimal. Only a handful of niche products have reached small, early market penetration over the course of 20 years. Ongoing improvements in performance and cost will be essential for more product categories to gain market share and start delivering significant energy savings.

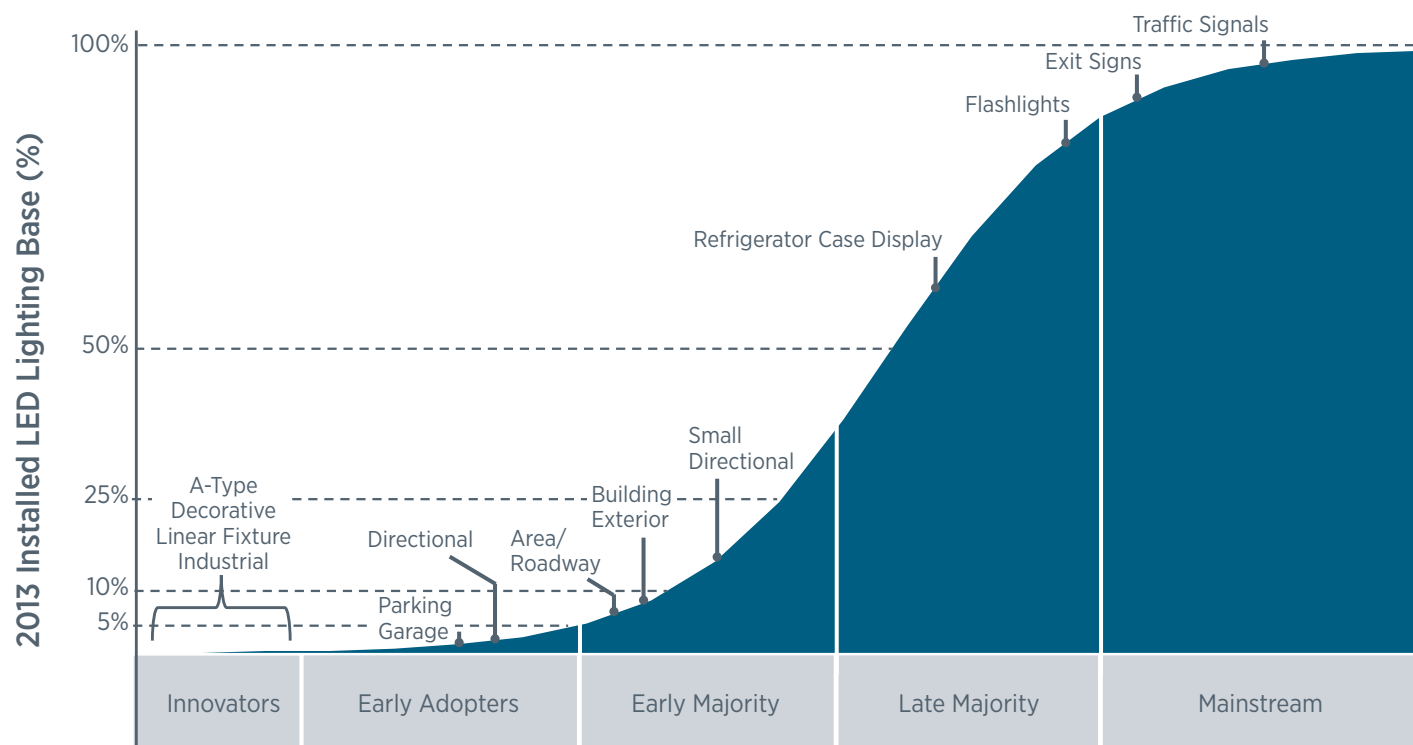
energy savings over the past 11 years—a remarkable return on the total DOE SSL program investment of about \$300 million over that same period.

Strong returns for U.S. taxpayers.

DOE has structured the Solid-State Lighting Program to generate the best possible “bang for the buck” for U.S. taxpayers. According to a recent National Academy of Sciences review, the program is delivering exactly that:

DOE has done an impressive job in leveraging a relatively small level of funding to play a leading role nationally and internationally in stimulating the development of SSL.

With ongoing progress, the benefits of program accomplishments will compound over time. By 2030, SSL could potentially reduce national lighting electricity use by nearly half—the annual equivalent to saving 3,000 trillion Btus, worth \$26 billion in today’s dollars. That would equate to the total energy consumed by 24 million American homes today and would reduce greenhouse gas emissions by 180 million metric tons—the equivalent of taking 38 million of today’s passenger vehicles off the road.



Keeping a Foot on the Accelerator

Although solid-state lighting has come a long, long way in a short time, the upside potential remains extraordinary. DOE has been instrumental in driving the industry forward. Now, by keeping a foot on the accelerator, our nation stands to magnify the benefits of SSL in saving energy, reducing carbon emissions, and enhancing our built environments.

What's ahead for solid-state lighting?

For DOE, realizing the full potential for energy efficiency improvements will remain front and center in setting priorities for targeted cost-shared R&D projects. Innovation will be essential in unlocking new levels of performance. For example:

- There is still substantial headroom for improving LED lighting efficiency. Researchers believe that phosphor-converted and hybrid LED packages can achieve peak efficacy around 250 lm/W using standard drive conditions.
- OLED technology is less mature than LED technology, and innovations are needed on multiple fronts to increase the efficiency, lifetime, and output of OLED devices. Manufacturing infrastructure investments will be essential to transition OLED products from the prototype stage to commercial viability. Since price is one of the biggest hurdles to widespread adoption, DOE works with industry to reduce costs through improvements in manufacturing equipment and processes.

Going forward, R&D priorities will include breakthrough improvements to lifetime, color quality and consistency, and lighting system performance, as well as value-added features that increase the competitiveness of SSL products. R&D also will target flexible production, testing, and monitoring technologies that



Through **DOE testing and demonstration** of emerging SSL products and systems, any technology problems are identified and intercepted early on. As a result, manufacturers gain invaluable feedback on how to improve their products.

will position the United States for sustained growth and leadership in SSL engineering and manufacturing.

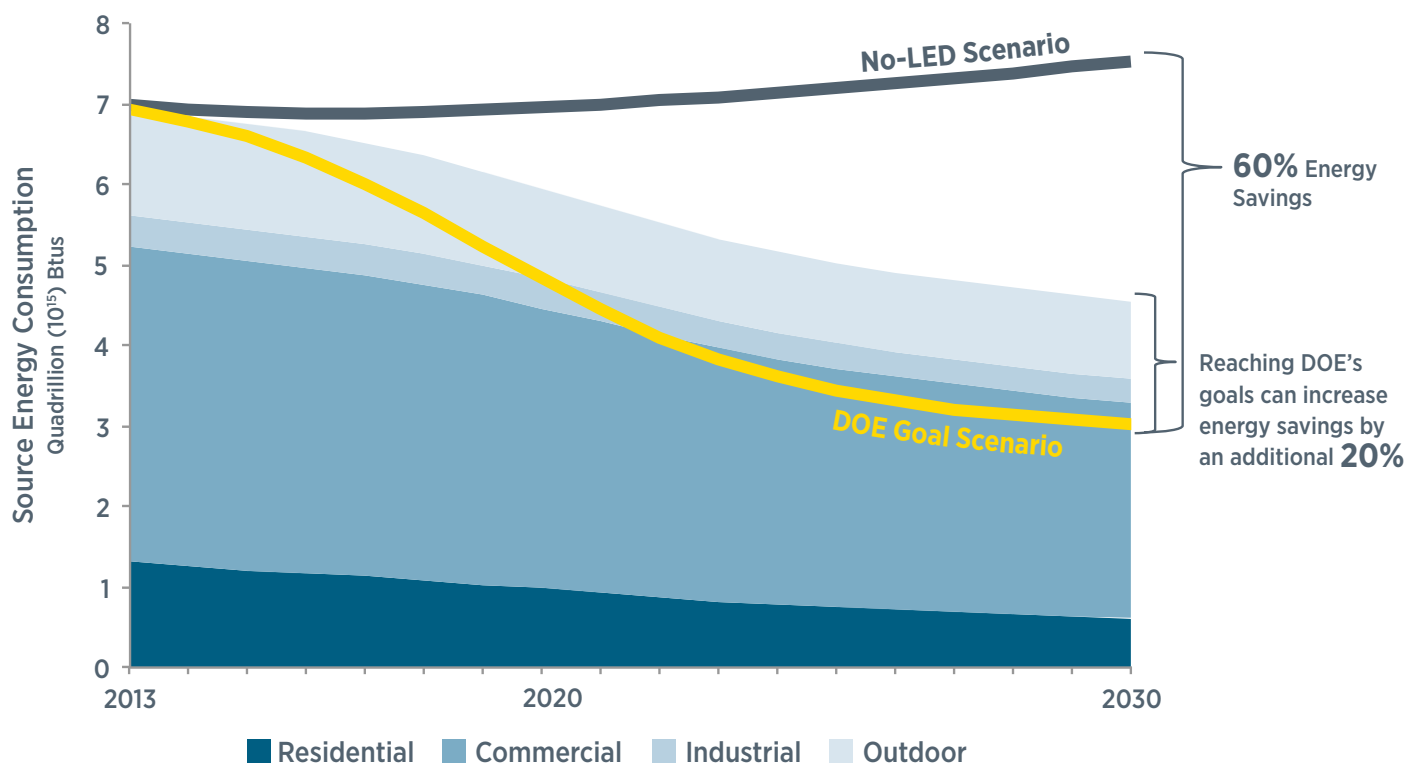
DOE will closely monitor new product introductions and technology advances, and provide field and laboratory evaluations of emerging products, particularly LED lighting systems that involve advanced controls. By identifying and characterizing performance issues in commercial products early on—and feeding that information back to manufacturers—DOE speeds the pace of technology improvement.

▼ **DOE spurs technology progress in SSL** by setting ambitious but achievable “reach” goals and co-funding vital research with industry partners.

DOE program strategies continue to keep pace with SSL technology.

Throughout the brief, exciting history of SSL, the DOE Solid-State Lighting Program has continually evolved to keep pace with the dynamic challenges of the industry. Yet two imperatives have remained constant: generating the greatest possible returns on taxpayer investments, and providing trusted, impartial data and analysis to guide researchers and manufacturers.

Moving forward, these same imperatives will continue to guide the program, as DOE invests strategically to open up new frontiers in SSL performance and to maximize benefits for our nation.



DOE Solid-State Lighting Program

The U.S. Department of Energy (DOE) is committed to realizing the full energy-saving potential of solid-state lighting. For more information, visit www.ssl.energy.gov.

U.S. DEPARTMENT OF
ENERGY | Energy Efficiency &
Renewable Energy

U.S. Department of Energy
Energy Efficiency & Renewable Energy
Building Technologies Office

DOE/EE-1149 • November 2014

Cover photos courtesy of (clockwise from left) Focal Point, Juno Lighting, Eureka Lighting, Blackjack Lighting